

PROCESS FOR PREPARING AN AQUEOUS DISPERSION OF A
QUATERNARY AMMONIUM SALT CONTAINING VINYL COPOLYMER

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BACKGROUND OF THE INVENTION

[0001] The present invention is directed toward ion-sensitive or triggerable, water-dispersible or water-soluble cationic polymers, and more particularly to a method of making such cationic polymers.

[0002] It has been proposed that ion-triggerable cationic polymers be used as a binder for fibrous webs in the manufacture of disposable products such as diapers, wet wipes, incontinent garments and feminine care products. It has been discovered that such ion-triggerable cationic polymers have adequate in-use strength to bind different fibrous layers of disposable products together, but will readily dissolve or disintegrate in water providing the ability to dispose of the product by flushing it down a toilet, if desired. The polymer has a "trigger property" meaning that the polymer is insoluble in monovalent and/or divalent salt solutions at concentrations above about 0.3% by weight, but is soluble when the solution is diluted with water, such as when the product is discarded into water contained in a toilet. This allows the fibrous web to break apart and disperse enabling the product to be flushable.

[0003] Ion-sensitive polymers comprised of acrylic acid and alkyl or aryl acrylates are disclosed in U.S. Patent 5,312,883, U.S. Patent 5,317,063 and U.S. Patent 5,384,189. The ion-triggerable polymers disclosed in these patents are acrylic acid-based terpolymers, which comprise partially neutralized acrylic acid, butyl acrylate and 2-ethylhexyl acrylate. The disclosed terpolymers, however, are limited in their application as a flushable binder material to geographical areas having soft water rather than hard water because these terpolymers fail to adequately disperse in water containing more than about 15 parts per million Ca^{2+} and/or Mg^{2+} ions.

[0004] In U.S. Patent 6,423,804 there is disclosed a modification of the acrylic acid terpolymers of the above-referenced '883, '063 and '189 patents. More specifically, the '804 patent discloses a sulfonate anion modified acrylic acid terpolymer which

has improved dispersability in relatively hard water, as compared to the unmodified terpolymers of the above-referenced patents. The sulfonate modified terpolymer of the '804 patent is prepared from four monomers, namely, acrylic acid, a sulfonate containing monomer such as 2-acrylamido-2-methyl-1-propanesulfonic acid (AMPS), or the sodium salt thereof (NaAMPS), butyl acrylate and 2-ethylhexyl acrylate. These four monomers are dissolved in an acetone/water mixture. The monomer solution is deoxygenated, and the monomer solution along with an initiator dissolved in acetone are then added together and polymerized. Distillation removes the excess acetone and deionized water is then added to reduce the viscosity of the polymer solution.

[0005]

Although numerous solution polymerization techniques are known, there remains a need for providing a method of preparing ion-triggerable cationic polymers because the anionic acrylic acid based ion-sensitive polymers and the sulfonate anion modified acrylic acid terpolymers of the above-referenced patents, when used as binders for personal care products, such as wet wipes, typically have reduced initial sheet wettability, increased dry sheet stiffness, increased sheet stickiness, reduced binder sprayability and relatively high product cost. Preferably, the process should desirably result in high yield of the polymer, be relatively economical, and be scaleable up to a commercial basis. In addition, the process must provide a cationic polymer having relatively high molecular weight because high molecular weight provides the strength necessary for use as a fibrous web binder. Finally, the process should be environmentally friendly, i.e. it should preferably not use any hazardous air pollutant (HAP) and/or any volatile organic compound (VOC) which might contribute to air pollution.

SUMMARY OF THE INVENTION

[0006]

A method of making an ion triggerable cationic polymer comprises solution copolymerizing one or more vinyl-functional cationic monomers, one or more water insoluble or hydrophobic vinyl monomers with alkyl side chains up to 4

carbons long, and, optionally, a minor amount of one or more vinyl monomers with linear or branched alkyl groups longer than 4 carbons, alkyl hydroxy, polyoxyalkylene, or other functional groups. The solution polymerization is accomplished by free radical polymerization in a mixture of acetone and water. After the copolymerization is complete, the acetone solvent is removed and replaced with water to give an aqueous dispersion of the ion-triggerable cationic polymer.

[0007] More specifically, the steps of the process include preparing a mixed solvent solution of water and acetone, and heating the solvent solution. Preferably, the solvent solution is heated to reflux. Thereafter, the process steps include mixing with the solvent solution one or more vinyl-functional cationic monomers, one or more hydrophobic vinyl monomers having alkyl side chains of 1-4 carbon atoms, optionally about 0% to 30 mole % of one or more other vinyl monomer with linear or branched alkyl groups longer than 4 carbons, alkyl hydroxy, polyoxyalkylene, or other functional group, and a free radical initiator to form a reaction mixture. The reaction mixture is heated for a sufficient amount of time and at a sufficient temperature to polymerize the monomers and produce the ion-triggerable cationic polymer. After the polymerization, acetone is removed and water is added to provide an aqueous dispersion of the ion-triggerable cationic polymer, substantially free of all of the acetone. The removal of acetone and the addition of water steps may be performed in any sequence, including simultaneously. The preferred vinyl-functional cationic monomer is a quaternary ammonium salt containing vinyl monomer such as [2-(acryloxy)ethyl] trimethyl ammonium chloride, and the preferred hydrophobic vinyl monomer is methyl acrylate.

[0008] The process preferably includes recycling the acetone to be re-used as the acetone ingredient of the initial acetone and water solvent solution. Recycling acetone has the advantage of making the present process commercially economical and feasible. Additionally, acetone is not listed as a volatile organic compound (VOC) and/or as a hazardous air pollutant (HAP) which is also advantageous for

commercialization purposes. Also, acetone advantageously achieves an end product of relatively high molecular weight as opposed to other lower alcohols or lower ketones such as for example methanol or ethanol that might be used as a solvent for the vinyl monomer. Finally, acetone is easier to remove and recover from the reaction mixture in high purity than other solvents so that it can be recycled for use in subsequent polymerization reactions.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0009]

The polymers synthesized in accordance with the present invention are useful as binders and structural components for air-laid and wet-laid nonwoven fabrics for applications, such as body-side liners, fluid distribution materials, fluid in-take materials (surge) or cover stock in various personal care products. The polymer formulations of the present invention are particularly useful as a binder material for flushable personal care products, particularly wet wipes for personal use, such as cleaning or treating skin, make-up removal, nail polish removal, medical care, and also wipes for use in hard surface cleaning, automotive care, including wipes comprising cleaning agents, disinfectants, and the like. The flushable products maintain integrity or wet strength during storage and use, and break apart or disperse after disposal in a toilet when the salt or ion concentration falls below a critical level. Suitable substrates for treatment include tissue, such as creped or uncreped tissue, co-form products, hydroentangled webs, airlaid mats, fluff pulp, nonwoven webs, and composites thereof.

[0010]

The present invention is directed to a method of making ion-sensitive or triggerable cationic polymers that are water-dispersible or water-soluble for use as the binder for the nonwoven fabrics referred to above. The binder provides strength in the dry state, but more importantly, helps maintain a desired level of strength in the wet state by ion-triggerability. A controlled concentration of salt in the wetting solution insolubilizes the binder and allows it to function as an adhesive for the web. When the product, preferably a wet wipe is discarded into the

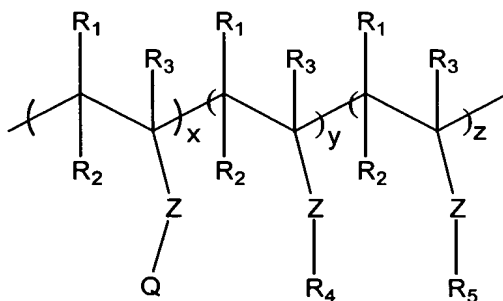
wastewater stream, the salt concentration is diluted, the binder becomes soluble, and the strength drops below a critical level. The ion-triggerable polymers thus have a "trigger property," such that the polymers are insoluble in a wetting composition comprising an insolubilizing agent of a particular type and concentration, such as monovalent and/or divalent salt solutions at concentrations above about 0.3% by weight, but are soluble when diluted with water, including hard water with up to 200 ppm (parts per million) calcium and magnesium ions. This allows the web to break apart into small pieces and, ultimately, disperse.

[0011]

The ion-triggerable cationic polymers are the polymerization product of one or more vinyl-functional cationic monomers, and one or more hydrophobic vinyl monomers with alkyl side chain sizes of up to 4 carbons long. In a preferred embodiment the ion-triggerable cationic polymers are the polymerization product of a vinyl-functional cationic monomer, and one or more hydrophobic vinyl monomers with alkyl side chain sizes of up to 4 carbons long incorporated in a random manner. Additionally, a minor amount, i.e. about 0 to 30 mole %, of one or more other vinyl monomers with linear or branched alkyl groups longer than 4 carbons, alkyl hydroxy, polyoxyalkylene, or other functional groups may be employed. The ion-triggerable cationic polymers function as adhesives for tissue, airlaid pulp, and other nonwoven webs and provide sufficient in-use strength (typically >300 g/in.) in salt solutions, especially sodium chloride. The nonwoven webs are also dispersible in tap water (including hard water up to 200 ppm as metal ion), typically losing most of their wet strength (<30-75 g/in.) in 24 hours, or less.

[0012]

The generic structure for the ion-triggerable cationic polymers polymerized in accordance with the method of the present invention is shown below:



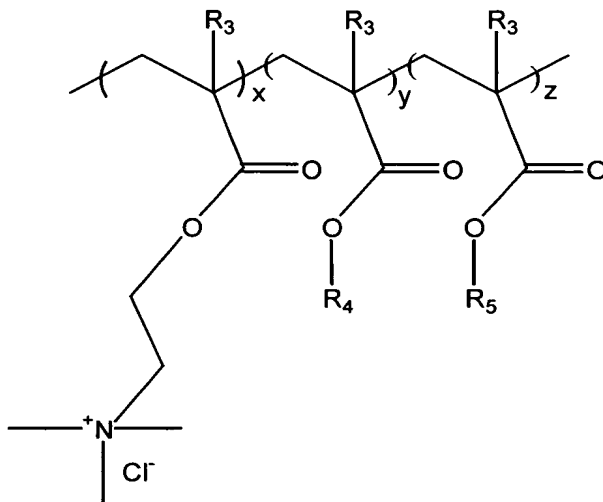
wherein $x = 1$ to about 15 mole percent; $y =$ about 60 to about 99 mole percent; and $z = 0$ to about 30 mole percent; Q is selected from C_1-C_4 alkyl ammonium, quaternary C_1-C_4 alkyl ammonium and benzyl ammonium; Z is selected from $-O-$, $-COO-$, $-OOC-$, $-COHN-$, and $-NHCO-$; R_1 , R_2 , R_3 are independently selected from hydrogen and methyl; R_4 is selected from a C_1-C_4 alkyl, i.e. methyl, ethyl, propyl and butyl; and R_5 is selected from hydrogen, methyl, ethyl, butyl, ethylhexyl, decyl, dodecyl, hydroxyethyl, hydroxypropyl, polyoxyethylene, and polyoxypropylene. Vinyl-functional cationic monomers useful in the method of the present invention desirably include, but are not limited to, [2-(acryloxy)ethyl] trimethyl ammonium chloride (ADAMQUAT); [2-(methacryloxy)ethyl] trimethyl ammonium chloride (MADQUAT); (3-acrylamidopropyl) trimethyl ammonium chloride; N,N-diallyldimethyl ammonium chloride; [2-(acryloxy)ethyl] dimethylbenzyl ammonium chloride; (2-(methacryloxy)ethyl] dimethylbenzyl ammonium chloride; [2-(acryloxy)ethyl] dimethyl ammonium chloride; [2-(methacryloxy)ethyl] dimethyl ammonium chloride. Precursor monomers, such as vinylpyridine, dimethylaminoethyl acrylate, and dimethylaminoethyl methacrylate, which can be polymerized and quaternized through post-polymerization reactions are also possible. Monomers or quaternization reagents which provide different counter-ions, such as bromide, iodide, or methyl sulfate are also useful. Other vinyl-functional cationic monomers which may be copolymerized with a hydrophobic vinyl monomer are also useful in the present invention.

[0013]

Desirable hydrophobic monomers for use in the ion-sensitive cationic polymers of the present invention include, but are not limited to, branched or linear C_1-C_{18} alkyl vinyl monomers, preferably C_1-C_4 alkyl vinyl ethers, vinyl esters, acrylamides, acrylates, methacrylates, and other monomers that can be copolymerized with the cationic monomer. As used herein the monomer methyl acrylate is considered to be a hydrophobic monomer. Methyl acrylate has a solubility of 6 g/100 ml in water at 20°C.

[0014]

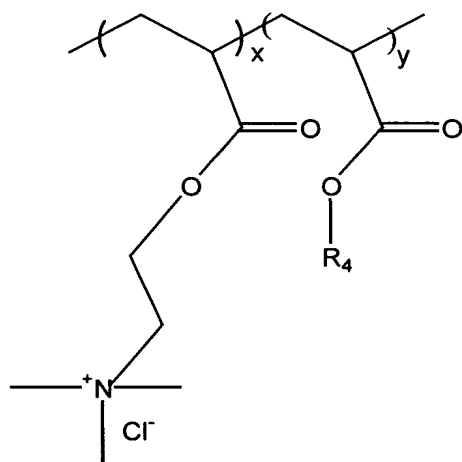
In a preferred embodiment, the binder is the polymerization product of a cationic acrylate or methacrylate and one or more alkyl acrylates or methacrylates having the generic structure:



wherein $x = 1$ to about 15 mole percent; $y =$ about 60 to about 99 mole percent; and $z = 0$ to about 30 mole percent; R_4 is selected from a $\text{C}_1\text{-C}_4$ alkyl, i.e. methyl, ethyl, propyl and butyl; R_5 is selected from ethylhexyl, decyl, dodecyl, hydroxyethyl, hydroxypropyl, polyoxyethylene, and polyoxypropylene.

[0015]

In an especially preferred embodiment, the ion-triggerable polymer has the structure:



wherein $x = 1$ to about 15 mole percent; $y =$ about 85 to about 99 mole percent and R_4 is C_1 - C_4 alkyl. In a most desirable embodiment, when R_4 is methyl, $x = 3$ to about 6 mole percent; $y =$ about 94 to about 97 mole percent.

[0016] The ion-triggerable cationic polymers may have an average molecular weight that varies depending on the ultimate use of the polymer. The ion-triggerable cationic polymers have a weight average molecular weight ranging from about 10,000 to about 5,000,000 daltons. More specifically, the ion-triggerable cationic polymers have a weight average molecular weight ranging from about 25,000 to about 2,000,000 daltons, or, more specifically still, from about 120,000 to about 1,000,000 daltons.

[0017] The ion-triggerable cationic polymers may be prepared according to a variety of polymerization methods, desirably a solution polymerization method. A suitable solvent for the polymerization method is a mixed solvent solution of water and acetone. The water functions as a solvent for the cationic monomer, and the acetone functions as a solvent for the vinyl monomer. The solvent solution preferably contains from about 50% to about 90% by weight acetone, more preferably about 60% to about 85% acetone, and most preferably about 70% to about 75% acetone, with the remainder of the solution being water (i.e. from about 10% to about 50% by weight). In any case, a sufficient amount of acetone must be used to dissolve all of the vinyl monomer and initiator used and a sufficient amount of water must be used to dissolve all of the cationic monomer used in the process.

[0018] In the polymerization methods of the present invention, free radical polymerization initiators are used. Selection of a particular initiator may depend on a number of factors including, but not limited to, the polymerization temperature, the solvent, and the monomers used. Suitable polymerization initiators for use in the present invention include, but are not limited to, azo initiators such as 2,2'-azobisisobutyronitrile, 2,2'-azobis(2-methylbutyronitrile), 2,2'-azobis(2,4-dimethylvaleronitrile), and 2,2'-azobis(N,N'-dimethyleneisobutylamidine). Peroxide initiators such as di(n-propyl) peroxydicarbonate, di(sec-butyl)

peroxydicarbonate, di(2-ethylhexyl) peroxydicarbonate, t-amyl peroxyneodecanoate, t-butyl peroxyneodecanoate, t-amyl peroxy-pivalate, and t-butyl peroxy-pivalate may also be used. The amount of polymerization initiator may desirably range from about 0.01 to 5 weight percent based on the total weight of monomer present.

[0019] The polymerization temperature may vary depending on the polymerization solvent, monomers, and initiator used, but in general, range from about 20°C to about 90°C. Polymerization time generally ranges from about 2 to about 8 hours.

[0020] After polymerization is complete, substantially all of the acetone from the reaction mixture is removed therefrom so that the acetone may be re-used or recycled. Recycling acetone is a feature which results in the process being relatively economical and feasible for commercial purposes. Acetone is preferably removed from the reaction mixture by distillation. However, any other method known in the art may also be used, e.g. an extrusion process and/or a thin film evaporator process. Once removed from the reaction mixture, the acetone is collected and recycled for use as the acetone ingredient of the initial acetone and water solvent solution. It may also be necessary to add an amount of make-up acetone when preparing the acetone/water solvent solution using the recycled acetone since generally it is difficult to recover 100% of the acetone from the reaction mixture.

[0021] It has been discovered that the use of acetone as the solvent for the vinyl monomer is essential to the process of the present invention. As noted above, acetone may be recycled thus reducing the amount of raw material needed in the process. Other water miscible lower alcohols and/or lower ketones are relatively more difficult to remove from the reaction mixture, and are not easy to obtain in high concentrations in the presence of water, which is critical for recycling of the solvent. Additionally, acetone is not listed as a volatile organic compound (VOC) and/or a hazardous air pollutant (HAP). Thus, there is no restrictive special handling required which might substantially increase the cost of the process.

Finally, it has been discovered that acetone, but not other lower alcohols and/or lower ketones, used in the present polymerization process advantageously results in an end product cationic polymer having relatively high molecular weight. High molecular weight provides the high strength which is needed to use the polymer as a fibrous web binder. Preferably, the molecular weight of the cationic polymer, as measured by its inherent viscosity (a technique well known in the art), is equal to or greater than 1.0 and more preferably equal to or greater than 1.6.

EXAMPLES

[0022] Example 1: Preparation and Evaluation of an Ion Sensitive Cationic Polymer;

[0023] Preparation:

[0024] Acetone (a product of VWR of Westchester, PA, 444.14 grams) and deionized water (148.05 grams) were charged to a 3-liter round bottom flask equipped with a reflux condenser, stirring means, and a thermocouple. This mixture was cooled in an ice water bath and bubbled with nitrogen for 20 minutes to remove oxygen. After the 20 minutes, the reaction mixture was maintained under a positive pressure of nitrogen and the temperature was raised to the boiling point of the mixture (about 60°C) using a heating mantle as the heat source.

[0025] A first monomer mixture was prepared by mixing 9.15 grams of deionized water and 39.32 grams of Adamquat MC-80 (an 80% aqueous solution of [(2-acryloxy)ethyl]trimethylammonium chloride, a product of Atofina, Philadelphia, PA). A second monomer mixture was prepared by mixing 335.26 grams of methyl acrylate (Sigma-Aldrich, St. Louis, MO), 51.08 grams acetone, and 2.23 grams VAZO 52 (a free radical initiator available from DuPont of Wilmington, DE). These two monomer mixtures were added simultaneously over the course of 4

hours to the flask containing the refluxing acetone/ water mixture. At the end of the monomer addition, 5.19 grams of deionized water and 15.57 grams of acetone were added to the reaction mixture. The reaction mixture was heated for an additional 4 hours after the end of the monomer addition. On cooling the product of the reaction is a clear polymer solution of about 35% solids with a viscosity of 1220 cps (Brookfield viscometer, room temperature, RVT spindle #2, 20 speed). Monomer conversion was determined to be 96% based on analysis by gas chromatography.

[0026] To remove the acetone, the flask was fitted with distillation condenser and a collection flask. Deionized water (1220 grams) was added to the polymer solution and the temperature was raised. A light flow of nitrogen was maintained over the mixture to assist the removal of the distillate. Distillate (608 grams) was recovered over about 4 hours as the temperature of the product rose from room temperature to about 99°C. The distillate composition was found to contain 73.0% acetone and 1.5% methyl acrylate by gas chromatography. Since no other materials were identified by gas chromatography, the remaining 25.5% is thought to be water.

[0027] At the end of the distillation, the remaining aqueous mixture was cooled and a mixture of 4.8 grams of 50% hydrogen peroxide (Sigma-Aldrich of St. Louis, MO) and 8.0 grams of deionized water was added. The aqueous polymer mixture was slightly hazy. The pH of this material was 3.9, the viscosity was 40 centipoise, and the percent solids was 21.7. The polymer contains less than 0.5% by weight residual acetone. The inherent viscosity of the polymer, a measure of molecular weight, was 1.54.

[0028] Product Evaluation:

[0029] *Thermally-bonded Air-laid Nonwoven*

[0030] A weak, thermally-bonded air-laid (TBAL) nonwoven test substrate was fabricated from Weyerhaeuser NF405 wood pulp and KoSA T-255 binder fibers.

The binder fiber had a polyester core and a polyethylene sheath that melts at approximately 130 °C. The air-laid web was formed using approximately 4% binder fiber and thermally bonded above the melting temperature of the sheath. The TBAL basesheet had an average basis weight of 51 gsm and an average caliper of 1.0 mm. The TBAL substrate had a residual cross-direction (CD) wet tensile strength of approximately 30 g/in. in water. A uniform and consistent amount of each binder was applied to the substrate via a pressurized spray unit. This handsheet spray unit is designed to closely resemble the operation of a commercial airlaid machine using liquid or emulsion binders, but on a much smaller scale. The equipment is housed in a small-framed housing, which can be placed, under a laboratory hood. The unit has a stationary sample holder (10"x13") in the center of the unit and a moveable spray header directly over the sample holder. A vacuum box is installed under the sample holder section to help draw the binder into the web during the application process. The hand-sheet is placed on the vacuum box and the spray head is moved across the substrate as the binder is sprayed in a flat V-shaped pattern. The binder is housed in a pressurized storage vessel located outside of the spray cabinet and is delivered to the spray nozzles via high pressure flexible tubing. The spray header with its spray nozzle (Spraying Systems Company) assembly is moved over the sample by means of a belt driven slide assembly, providing the desired application uniformity and speed. The spray header could be operated at speeds close to 180 fpm and the spray atomization pressure could be set as high as 200 psig. The sample was manually removed and dried in a Werner Mathis, Model LTV Through-Air Dryer (TAD) at the indicated temperatures and for the indicated times. Final basis weight of the samples with binder was approximately 63-64 gsm.

[0031] *Tensile Testing*

[0032] A SinTech 1/D tensile tester with Testworks 3.03 version software was used for all sample testing. A 100 Newton load cell with pneumatic grips was utilized.

A gauge length of 2 in. and a crosshead speed of 12 in./min. were employed. The peak load values (in g/in.) of sample replicates were recorded and averaged and reported as machine-direction wet tensile strength (MDWT) or cross-direction wet tensile strength (CDWT), depending on how the measurement was made.

[0033] The in-use strength of each sample was simulated by either 1) soaking the tensile sample in a salt solution of desired salt type and concentration or a formulated wetting solution containing salt, or 2) applying one of the aforementioned solutions at a fixed add-on (typically 200%-300%). The samples were allowed to equilibrate for several hours before measuring the tensile strength. Disposal strength or dispersibility was assessed by transferring samples treated as "in-use" into an excess (typically 800 mL) of deionized water or hard water of specified hardness level (as metal ion) and allowing them to soak for the indicated amount of time before the tensile strength was measured.

[0034] *Results*

uncorrected CDWT (g/in) on TBAL, 25% Binder drying oven conditions: 180°C, 23 seconds		
Example	4% NaCl (soaked overnight)	4% NaCl (soaked overnight) ↓ Deionized Water (1 hour soak)
1	343 ± 27	50 ± 5

[0035] Examples 2-5: Preparation and Evaluation of Ion Sensitive Cationic Polymers Using Recycled Distillate

[0036] Preparation:

[0037] The polymer composition of Example 1 was prepared in a manner substantially similar to the procedure of Example 1. Since the distillate contained

methyl acrylate, some Adamquat and VAZO 52 were added at the start of the polymerization to normalize the monomer composition in the flask. Likewise, some correction was made for slight differences in the acetone/ water ratio in the distillate. The following is a tabulation of these changes and the resulting products of the reaction. The acetone distillate from Example 1 was used in the polymerization process of Example 2 while the acetone distilled from Example 2 was used in the polymerization process of Example 3. Likewise, the acetone distilled from Example 3 was used in the polymerization process of Example 4 and the acetone distilled from Example 4 was used in the polymerization process of Example 5.

<u>Parameter</u>	<u>Example 2</u>	<u>Example 3</u>	<u>Example 4</u>	<u>Example 5</u>
Grams of distillate from previous batch in flask	601.2	598	602.4	525.0
Grams of Adamquat in flask	1.05	1.19	1.20	0.99
Grams of VAZO 52 in flask	0.06	0.07	0.07	0.06
Grams of fresh acetone in flask	1.37	1.6	1.56	76.9
Grams of fresh water in flask	0.24	3.0	0.28	0.23
Monomer feed 1 Adamquat	38.27	38.13	38.12	38.33
Monomer mix 1 deionized water	8.92	6.16	8.88	8.93
Monomer mix 2 methyl acrylate	326.26	325.1	325.02	326.86
Monomer mix 2 acetone	49.71	49.48	49.52	49.81
Monomer mix 2 VAZO 52	2.17	2.16	2.16	2.17
Grams distillate collected	598.7	627.52	617.9	639.5
Distillate composition %acetone	74.0	74.0	70.2	72.5
Distillate composition % methyl acrylate	1.7	1.7	1.6	1.7

<u>Parameter</u>	<u>Example 2</u>	<u>Example 3</u>	<u>Example 4</u>	<u>Example 5</u>
Aqueous product pH	4.0	4.0	4.1	4.1
Aqueous product viscosity	35	75	35	55
Aqueous product percent solids	21.3	22.3	21.4	22.3
Polymer inherent viscosity	1.54	1.50	1.52	1.52

[0038] These examples demonstrate the ability to collect the solvent distillate in amounts and compositions similar to the amount and composition of the contents of the flask in Example 1.

[0039] Product Evaluation:

[0040] The product evaluation was conducted in the same manner outlined in Examples 1.

	uncorrected CDWT (g/in) on TBAL, 25% Binder oven conditions: 180°C, 23 seconds	
	4% NaCl (soaked overnight)	4% NaCl (soaked overnight) ↓ Deionized Water (1 hour soak)
Example		
1	343 ± 27	50 ± 5
2	316 ± 36	60 ± 19
3	349 ± 40	68 ± 15
4	333 ± 20	67 ± 10
5	323 ± 25	55 ± 9

[0041] Conclusion:

[0042] Recycling of the acetone up to 5 times had no effect on the molecular weight of the polymer or on the performance of the polymer as a binder.

[0043] Examples 6-8: Another Preparation and Evaluation of Other Ion Sensitive Cationic Polymers Varying the Initiator Level

[0044] Example 6 Polymer Preparation:

[0045] Acetone (426.94 grams) and deionized water (133.84 grams) were placed in 3-liter flask following the procedure outlined in Example 1. The first monomer mixture was composed of 42.42 grams of Adamquat MC-80 and 45 grams of deionized water. The second monomer mixture was composed of 286.56 grams of methyl acrylate, 135 grams of acetone and 1.92 grams of VAZO52. The half life of the initiator is about 180 minutes at the reaction temperature. The monomer was added as indicated in Example 1. After the monomer addition, the reaction product was heated for an additional two hours before cooling. The reaction product is a clear 30% polymer containing solution with a viscosity of about 300 centipoise. Monomer conversion was 93.5%. The reaction solution was transformed to an aqueous polymer mixture by adding 800 grams of water and distilling off the acetone over about 6.5 hours. The aqueous final product had a pH of 4.0, a viscosity of 210 centipoise, and a percent solids of 25.5%. The final dry polymer product had an inherent viscosity of 1.49.

[0046] Example 7 Polymer Preparation:

[0047] The product was prepared in the same manner as Example 6, except the initiator level was lowered to 1.28 grams. The aqueous final product had a pH of 3.9, a viscosity of 87 centipoise, and a percent solids of 24.5%. The final dry polymer product had an inherent viscosity of 2.01.

[0048] Example 8 Polymer Preparation:

[0049] The product was prepared in the same manner as Example 6, except the initiator level was lowered to 0.64 grams. The aqueous final product had a pH of

3.8, a viscosity of 50 centipoise, and a percent solids of 25.5%. The final dry polymer product had an inherent viscosity of 3.08.

[0050] Product Evaluation:

[0051] The product evaluation was conducted in the same manner outlined in Example 1.

Example	CDWT in 4% NaCl (soaked overnight) (g/in)	CDWT after 1 hour soak in Deionized Water solution (g/in)
6	278 ± 25	47 ± 1
7	298 ± 23	103 ± 29
8	409 ± 15	245 ± 30 (1 h) 68 ± 3 (24 h)

[0052] Conclusion:

[0053] High molecular weight can be achieved with varying degrees of initiator. In addition, as the initiator is reduced CDWT increases and the dispersibility in water decreases.

[0054] Comparative Examples 1 and 2: Preparation and Evaluation of Ion Sensitive Polymers in Methanol and Ethanol

[0055] Comparative Example 1 Polymer Preparation:

[0056] Methanol (323.3 grams from VWR of Westchester, PA) was placed in a 3-liter flask and deoxygenated using the procedure of Example 1. A monomer mixture of 286.56 grams of methyl acrylate, 42.42 grams of Adamquat MC-80, 150 grams of methanol, and 0.64 grams of VAZO 52 was prepared. The monomer

mixture was added to the methanol solvent over the period of 4 hours. The temperature was held at 60°C throughout the monomer addition and the subsequent 2 hour reaction hold. The final product is a clear 40% polymer solution. The monomer conversion was 92%. The reaction solution was transformed to an aqueous polymer mixture by adding 800 grams of water and distilling off the methanol. The distillation required about 12 hours and an additional 300 grams of water to completely remove the methanol. The distillate contained a mixture of water and methanol. The aqueous final product had a pH of 4.0, a viscosity of about 250 centipoise, and a percent solids of 25.6% and a residual methanol level of 0.3% by weight. The final dry polymer product had an inherent viscosity of 1.68.

[0057] This example illustrates the propensity of methanol to limit the polymer molecular weight. The methanol reaction needs 1/3 the amount of initiator to reach the same molecular weight as the acetone/water mixture in Example 6. When the same amount of initiator was used in acetone/H₂O (Example 8), the molecular weight was significantly higher, as determined by inherent viscosity. The lower initiator levels when using methanol limit the ability to achieve even higher molecular weights. Decreasing the already low initiator level in the methanol system to increase molecular weight would lead to lower monomer conversion which decreases polymer yield. More importantly, it is to be noted that the distillation of methanol required a significantly longer time than when using acetone as the solvent. Additionally, methanol is considered a VOC and HAP material under US EPA regulations.

[0058] Comparative Example 2 Polymer Preparation:

[0059] An ion sensitive polymer was prepared in ethanol by replacing the methanol in comparative example 1 with ethanol. All other conditions were held constant. About 950 grams of water was added to the polymer solution and distilled. The distillate contained a mixture of water and ethanol. The aqueous final product had

a pH of 4.0, a viscosity of about 120 centipoise, and a percent solids of 25.7%. The final dry polymer product had an inherent viscosity of 0.42.

[0060] This example illustrates the propensity of ethanol to limit the polymer molecular weight. The ethanol reaction resulted in an unacceptably low molecular weight even when using 1/3 the amount of initiator as compared to the acetone/water mixture in Example 6. The lower initiator levels limit the ability to achieve the higher molecular weights needed for product performance. Additionally, ethanol is considered a VOC under US EPA regulations.

[0061] Product Evaluation:

[0062] The product evaluation was conducted in the same manner outlined in Example 1.

Comparative Example	uncorrected CDWT (g/in) on TBAL, 25% Binder drying oven conditions: 180°C, 23 seconds	
	4% NaCl (soaked overnight)	4% NaCl (soaked overnight) ↓ Deionized Water (1 hour soak)
1	325 ± 26	9 ± 15
2	36 ± 1	4 ± 3